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Investigation of the safety, accuracy, validity and reliability of a commercial GPS data recorder for use in studies of racing performance in homing pigeons

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ABSTRACT:

A commercially available GPS data recorder, the Photomate 887 Lite (TranSystem Inc., Taiwan), was tested for safety, accuracy, validity and reliability of use in studies of racing performance in homing pigeons A literature review was conducted on the potential safety of use issues for data recording devices in birds and animals and a study was designed to assess the ability of the Photomate to accurately determine distances in settings similar to its proposed use in the field. Safety issues generally relate to the method used to attach the device to the animal or the extra weight associated with the device. Historically pigeons have been able to carry devices with weights of up to 70g. Damage to birds was only associated with neglect of problems related to prolonged wearing of harnesses and include trauma from harnesses that had slipped or were fitted incorrectly. The GPS device was assessed for accuracy of recording while stationary and during motion. The percentages of total points found within a 3, 5 and 10 m radius of the real location were estimated as an overall measure of horizontal point spatial accuracy to be 62, 84 and 100%. The root mean square (RMS) position error of each replicate of the horizontal distance of individual GPS locations to the real location while in linear motion was 3.72 while that of the vertical was 46.60. The ratio of the actual distance travelled to the distance recorded by the GPS was compared as a measure of the track efficiency of the GPS data recorder to be 99.24%. It was concluded that, so long as the harness was correctly fitted and regularly monitored, the safety concerns would be minimal and the Photomate was sufficiently accurate, valid and reliable in horizontal point, dispersion and distance measurements for use in future studies in racing pigeons.

Keywords: Pigeons, Homing, GPS, Race performance

INTRODUCTION

Homing pigeons (*Columba livia*) have an exceptional ability to navigate over long distances and if released at unfamiliar locations, instinctively and immediately endeavour to return to their home lofts. This homing phenomenon is the basis for the sport of pigeon racing - a popular hobby throughout the world [1]. Despite the homing pigeon having been the subject of much study in relation to avian navigation [2-10], avian flight mechanics [11-20] and the availability of basic physiological [21,22], nutritional [23,24 and anatomical [25-30] information, there are surprisingly few scientific studies on factors that affect racing performance.

To compete in a race, a pigeon must have a permanent, unique numbered, closed ring purchased from the fancier's local club and placed on the bird's leg at about 5 days of age. Individual competing pigeons are entered into a race at the fancier's clubhouse where they are placed in baskets and taken away to be released at a predetermined time and location. A variety of competitive races are held during a season over distances measured, between the release site and the fancier's pigeon loft, to the nearest metre using global positioning system (GPS) technology [31].

In recent years, an electronic timing system based on radio frequency identification technology has made it much easier to collect accurate data on numerous individuals. Birds are fitted with a band that has a microchip which contains information that matches the permanent leg ring. When the bird enters the loft on its return, the chip is automatically read as the bird passes over a reading antenna and activates the time recorder. Therefore accurate flight times, which are adjudicated on by an official at the club, are downloaded from the loft's recorder and speeds can then be calculated for all the individual birds in a race based on the distance between release site and home loft, and the time taken to fly home [31]. The results from the returns of thousands of birds are used to determine winners of club races, federation races, combines, open competitions and national races.

The real speed of the bird flying home is likely to be underestimated since racing pigeons may not fly straight home (beeline distance); they may stop for a rest or to assess their route home or they may spend some added time circling at the release point [2].

Over the years, measurements of the distances flown home by pigeons have been determined in studies by tracking them using light aircraft [32,33] helicopter [34-37] radiotelemetry from the ground and air [38-43] and direction recorders [44-46]. More recently GPS data storage position recorders have proved promising in furthering the scientific investigation of avian navigation [47-51, 10, 52]. Although navigation is an

inherent ability of pigeons, many studies illustrate that it is not necessarily without variation and there appears to be a stage of learning to home, before pigeons reach a more steady state and settle into a route that, in some sites, appears to be stereotyped yet individually distinctive [53]. Since the race speed of a pigeon is a function of the distance travelled, an accurate method of measuring the actual flight path of the bird would be a useful adjunct to studies of racing performance. Although the technology is available commercially for use in racing pigeons the potential for scientific studies on racing performance remains to be exploited [54].

GPS is a navigation system, available worldwide, with a network of solar powered satellites placed into orbit by the U.S. Department of Defence [55]. There are three basic parts to the GPS system - the space segment, the control segment and the user segment.

GPS tracking allows collection of the most accurate animal locational data in all types of weather, as frequently as every second, to within 5 m. It can be used with reasonable confidence for relatively fine-scale habitat studies or when animals are in relatively fast motion [56-59].

A GPS data logger is a receiver that will record data on track, time and location for downloading. As technology improves and the size and weight of GPS receivers has become smaller, the number of science applications has increased. Such data recording has been used in the area of animal behaviour including population studies, bat flight, habitat use, bird foraging strategies, breeding behaviour and flight and migration studies [60, 49, 50, 61-88].

Although many of these studies initially used specifically designed GPS instruments, the increasingly wide availability of low cost commercially produced GPS loggers for recreational and other uses has resulted in some commercial loggers being trialled for medical studies [89].

GPS data recording in pigeons has been limited by the size and weight of receivers, recorders, batteries and antennae. Initially, instruments had to be specifically assembled for such tasks [49]. In the last few years, an increasing number of small, low-cost GPS data logger/receivers have been made commercially available in the recreational market, making them potential candidates for scientific studies in small animals. Some are only 20 g in weight and are simple to use in the field with only one start/stop button and all settings and configuration can be preset on a personal computer before measurements are commenced. The logged data can be downloaded with a USB connection to a personal computer for further analysis.

Specific validation studies of commercially available GPS instruments for use in human health research have shown some promise [89, 90]. However, other studies on the use of commercially available instruments in sport medicine studies caution about variability in different manufacturers' devices, with some validation studies showing poor accuracy during sprints over short distances (20-40 m) related to the use of different algorithms in triangulation calculations [91,92]. Conversely, accuracy and reliability in measurements of longer distances (600-8800 m) were found to be acceptable [92].

In this study a commercially available GPS data logger is tested for reliability, validity and accuracy in measuring horizontal point and linear displacement prior to its use in evaluation of pigeon flight tracks.

A commercially available GPS data recorder, the Photomate 887 Lite (TranSystem Inc., Taiwan), was obtained for use in pigeon flights. This GPS device is primarily designed for geo-tagging of photographs in the global tourism market. For ease of reading, the Photomate 887 Lite is further referred to as the Photomate. A similar GPS logger has been used in pigeons to study flock behaviour [93]. There are commercially available GPS data loggers for pigeon racing (LPT (Ledesma Pigeon Tracker) ®, Arona – Tenerife) but at over ten times the cost of the Photomate they were deemed too expensive for this project.

The Photomate measures (44 x 26 x 15) mm and weighs 20 g. If placed in a backpack type harness on a pigeon the total package would not exceed 3-5% of body weight [94, 95].

Despite the fact that such data recorders are commercially available to the public for recreational use by pigeon fanciers to monitor their birds and although it is probably true to say that some deleterious effects from the use of data recording devices can never be completely avoided [95] it is incumbent on researchers to ensure that such effects have minimal influence on the outcome of their studies or even the welfare of the animals under study. Therefore, it is prudent to address whether a device for multiple uses could affect the parameters to be studied such as flight behaviour or if the welfare of the birds might be compromised in any unforseen way or if such extremely low-cost GPS data logger/receivers are accurate enough for scientific studies.

MATERIALS AND METHODS

A literature review was conducted on the potential safety of use issues for data recording devices in birds and animals. A study was designed to assess the ability

of the Photomate to accurately determine distances in settings similar to its use in the field. It was assessed for accuracy of recording while stationary and during motion and errors of measurement, validity and reliability were calculated.

During both accuracy tests the Photomate was placed in a cotton backpack similar to that which would be harnessed to a pigeon in flight, to negate any effects that the backpack material may have on the readings obtained. The spatial accuracy of the Photomate was determined by estimating horizontal point (Test 1) and linear (Test 2) errors as in Elgethun *et al*. [96]. The horizontal point error represents the average distance from a position registered by a stationary GPS unit to the real position of the unit, whereas the linear error represents the deviation of the GPS readings on moving objects from the real location of their linear paths. The exact geographic location of the points used in the tests were derived by pinpointing them in Google™ Earth online and recording the latitude, longitude and altitude data from this source. In estimating the point error, corners of a nearby building were identified on the satellite view of Google™ Earth and the Photomate, programmed to record at a frequency of 1Hz was placed in the harness and left on the location for approximately 60 minutes. In estimating the line error the harnessed Photomate, recording at a frequency of 1 Hz, was held outside the back window of a car while travelling approximately 1 km up and down a straight roadway with an identified start and finish position. Each test was repeated 8 times to account for variations in accuracy due to satellite geometry at different times of the day. Data for Tests 1 and 2 were not filtered for outliers.

In Test 1, the percentages of total points found within a 3, 5 and 10 m radius of the real location were estimated as an overall measure of horizontal point spatial reliability. In Test 2 the perpendicular dispersion from the true track was calculated by trigonometry. The percentages of total points found within a 3, 5, 10 and 15 m radius of the real track were estimated as an overall measure of linear dispersal reliability. In both Tests the distance from the true position of each GPS location to the real location was used to estimate the root mean square (RMS) position error of each replicate. RMS represents one of the most used measures of GPS spatial accuracy [97]. In Test 2 the ratio of the actual distance travelled to the distance recorded by the GPS was compared as a measure of the track efficiency of the GPS data recorder and the percentage of total points found within 1, 2 and 3 degrees of the true direction of motion were estimated as an overall measure of linear direction reliability.

RESULTS AND DISCUSSION

Safety of use of data recording devices

The historical use of pigeons as carriers was reviewed in estimating potential detrimental effects due to carrying an extra load. In 1903, Julius Neubranner, a photography enthusiast, designed and patented a breast-mounted aerial camera for carrier pigeons that weighed 70 g and was successfully used for aerial photography especially in war time [98]. The first GPS recorder designed for use in scientific studies of pigeon navigation weighed 40 g when in harness [47]. A compass heading recorder that weighed 30 g including batteries has been designed for attachment to pigeons and used successfully [44]. GPS data loggers weighing 30 g and upgrades reported to weigh 12–14 g have been on the market for use in pigeons for a few years [54]. Finally pigeons are normally fed 30-50 g of mixed grains and pulses once or twice per day so are capable of carrying these weights.

However, potential welfare issues in using data recording devices in animals have been raised previously [99].

It is known that some device harnesses have caused pathology in birds associated with the length of time the birds had been carrying their devices without being checked. This ranged from one month to seven years [100, 101]. Harnesses can also cause problems due to poor or incorrect fitting, poor harness design or displacement of the body strap [101].

An informal standard which is commonly adopted for flying animals limits the size of the transmitter package to less than 5% of body mass [94]. Fuller *et al.* [102] arbitrarily recommend weights of 2 to 3 per cent of bodyweight of birds but there is a need to develop guidelines based on empirical evidence. The rationale for selecting 5% as the upper limit is not discussed in the literature and as seen above, heavier devices have been deployed with no adverse effects reported [103].

Good arguments, based on aerodynamic theories, suggest percentage of body weight is an inaccurate means of estimating sizes of devices that can be safely carried. Small birds can carry loads equalling a larger proportion of their body mass than large birds. Also energy cost of transporting a device may need to be considered [104, 103]. Energy cost may be relevant in racing birds as it could affect the performance being measured but it is only by carrying out studies using the available equipment that such questions might be answered.

GPS data recorder measurements of accuracy, validity and reliability

Table 1. Point (Test 1) and linear (Test 2) spatial accuracy of the Photomate GPS data logger

Test	Measure	Number of tests	Total number of readings	Actual mean	GPS mean	SD	Max	RMS	Percentage of readings within 3.00 m	5.00 m	10.00 m	15.00 m	% track efficiency
1	Position	8	28178	0	2.71	1.39	7.61	3.05	62	84	100		
2	Dispersion	8	391	0	1.44	2.47	10.50	3.72	76	85	95	100	
	Distance	8	391	944	950.86	3.94	957.06	8.21					99.24
	Altitude	8	16	80.50	126.87	4.92	132.62	46.60					
									Percentage of readings within				
									1 Degree	2 Degree	3 Degree		
	Bearings	4	201	313.09	312.94	0.12	313.04	0.01	94	100	100		
		4	190	133.1	133.30	0.09	134.00	0.04	88	98	100		

Table 1 shows the horizontal point (Test 1) and linear (Test 2) accuracy of the Photomate.

Table 1 illustrates that the Photomate was a valid measuring device for spot measurements and measurements while in motion. The device measured with a high degree of accuracy and good repeatability. However, GPS measurement of altitude was less accurate.

Early avian GPS devices relied on the information available about the general accuracy of GPS technology [49], but there is little published information about the accuracy, validity or reliability of commercially available GPS devices for use in birds. A commercial GPS data logger tested for tracking human movement in medical studies had a point RMS of 4.4 m and a linear RMS of 10.3 m [89] and this compares with results for the Photomate of 3.75 m and 3.72 m respectively. Although altitude measurement was less accurate than the two dimensional measurements, this is not unusual for GPS instruments and is due to geometry of satellite constellations and the shape of the earth [97].

CONCLUSIONS

With proper mitigation procedures in place to avoid any potential harness difficulties, the Photomate is a useful device for future studies in racing pigeons that measure dispersion and distances travelled although studies that involve the measurements of altitude may need to be carefully evaluated.

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